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# **The Return On Investment Of Implementing A Continuous Monitoring System In General Medical-Surgical Units**

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**Abstract:** [max. 300 words]

**Objective:** To evaluate the cost savings attributable to the implementation of a continuous monitoring system in a medical-surgical unit, and to determine the return on investment (ROI) associated with its implementation.

**Design:** ROI analysis.

**Setting:** A 316-bed community hospital.

**Patients:** Medicine, surgery or trauma patients admitted or transferred to a 33-bed medical-surgical unit.

**Intervention:** Each bed was equipped with a monitoring unit, with data collected and compared in a nine-month pre-implementation period to a nine-month post-implementation period.

**Measurements and main results:** Two models were constructed: a base case model (A) in which we estimated the total cost savings of intervention effects, and a conservative model (B) in which we only included the direct variable cost component for the final day of length of stay and treatment of pressure ulcers. In the 5-year ROI model, the monitoring system saved between \$3,268,000 (Conservative Model B) and \$9,089,000 (Base Model A), given an 80% prospective reimbursement rate. A net benefit of between \$2,687,000 (\$658,000 annualized) and \$8,508,000 (\$2,085,000 annualized) was reported, with the hospital breaking even on the investment after 0.5 and 0.75 of a year, respectively. The average net benefit of implementing the system ranged from \$224 per patient (Model B) to \$710 per patient (Model A) per year. A multi-way sensitivity analyses was performed using the most and least favorable conditions for all variables. In the case of the most favorable conditions, the analysis yielded a net benefit of \$3,823,000 (Model B) and \$10,599,000 (Model A), and for the least favorable conditions, a net benefit of \$715,000 (Model B) and \$3,386,000 (Model A). The ROI for the sensitivity

analysis ranged from 127.1% (25.4% annualized) Model B to 601.7% (120.3% annualized) Model A for the least favorable conditions, and from 627.5% (125.5% annualized) Model B to 1739.7% (347.9% annualized) Model A for the most favorable conditions.

**Conclusions:** Implementation of this monitoring system was associated with a highly positive ROI. The magnitude and timing of these expected gains to the investment costs may justify the accelerated adoption of this system across remaining inpatient non-ICU wards of the community hospital.

## Introduction

Care of critically ill patients is costly. An estimated 27% of Medicare costs are associated with intensive care unit (ICU) care. However, hospitals only receive 83% reimbursement for these patients, generating an overall \$5.8 billion loss to hospitals annually in the U.S.(1) In the 24 hours prior to ICU admission, as many as 80% of these patients will have had abnormal values for heart rate, respiratory rate and oxygenation.(2) Subtle changes in the vital signs of patients in general care units can indicate that a health crisis is imminent. Failing to recognize and promptly respond to these early warning signs can increase patient morbidity and mortality, as well as length of hospital stay and costs.(3) Early detection of patient deterioration in general care units should be a top priority for healthcare institutions.

Monitoring systems can help facilitate timely interventions for these high-risk patients. They can provide an added layer of care by continually observing hospitalized patients and drawing attention to those who shown signs of deterioration. In addition to providing information on patients' vital signs, some systems can also help identify those who have been immobile for extended periods of time. Pressure ulcers frequently occur in patients with impaired mobility or sensation, and are one of the most significant and costly health complications affecting patients in acute care hospitals. In 2006, the Agency for Healthcare Research and Quality reported an 80% increase in the diagnosis of pressure ulcers during hospital stays since 1993.(4) This alarming rise in pressure ulcers contributes to U.S. hospital costs, with an estimated \$11 billion spent annually on their treatment.(5) It is generally accepted that prevention is better than cure; current pressure ulcer prevention strategies have mostly been either ineffective or too expensive for widespread use.(6)

The EarlySense<sup>TM</sup> (EarlySense Inc., Waltham, MA) system has been approved by

the Federal Drug Administration to monitor patient heart rate, respiratory rate and bed movements in the hospital setting.(7, 8) In this system, a piezoelectric sensor is placed under the patient's mattress and it automatically measures, accumulates, analyzes and displays their vital signs on a bedside monitor and central nurse station, without need for activation or patient/nurse contact with the device. The system can proactively alert staff of untoward events, escalate particular alerts that are not responded to, and report alert response times and protocol compliance. A validation study(7, 9) and a before-and-after controlled clinical trial,(10)(11) suggest that the EarlySense™ monitoring system accurately measures patients' continuous heart and respiratory rate in real time. This, in turn, can lead to quicker intervention and treatment of patients whose clinical condition is deteriorating in general care units, fewer unplanned ICU admissions, and can potentially result in significant cost savings. Our objective was to estimate the cost savings attributable to the implementation of the continuous monitoring system in a general medical-surgical unit, and to determine the return on investment (ROI) associated with its implementation.

## **Materials and Methods**

### *Study design and participants*

We performed a financial analysis of implementing the EarlySense™ monitoring system (Waltham, MA.) with the primary outcome measure of net cost savings per patient per year. Two models were constructed: a base case model (A) in which we estimated the total cost savings of intervention effects (i.e., reduction in length of stay (LOS), ICU LOS and treatment of pressure ulcers), and a conservative model (B) in which we only included the direct variable cost component for the final day of LOS and treatment of pressure ulcers (the last day usually being of lower cost compared to those prior). Direct variable costs represent the impact of the intervention on the hospital's

cash flow better than total costs, which include allocated overhead and fixed capital costs that remain unaffected by short-term fluctuations in avoided adverse events or census. The model was framed from the perspective of the health care organization, and data on costs and outcomes were obtained from our before-and-after controlled study conducted at a 316-bed community hospital in Los Angeles (California Hospital Medical Center-CHMC).(10) The hospital includes a 33-bed medical-surgical unit, which typically cared for medical, surgical or trauma patients. Each bed was equipped with an EarlySense™ unit that alerted nurses when the patient had left the bed, was agitated, needed to be turned, or when their condition deteriorated. Data were collected and compared in a nine-month pre-implementation period (Jan 2009 - Sept 2009) to a nine-month post-implementation period (Nov 2009 - Jul 2010). The CHMC research committee approved the study protocol for this analysis.

### *Implementation Costs*

Capital costs, one-time noncapital costs, and ongoing annual operational costs associated with the implementation of EarlySense™ monitoring system were obtained from both the study site and EarlySense Inc. Capital implementation costs included the cost of the hardware (i.e., the cost of the sensor per bed, bedside monitor, one central monitor, two large screen hall displays, and one nurse manager office display), software costs (the cost of obtaining a license), and other implementation costs (i.e., \$600 per bed for IT infrastructure and \$40 per bed for installing wall adapter for bedside monitor). One-time, noncapital implementation costs included training of hospital personnel (i.e., two hours per nurse per year and one hour per nurse assistant per year). In this analysis, EarlySense Inc. and the site's financial team distinguished between capital and one-time noncapital costs (see Table 1). Annual ongoing operational costs included the training or retraining of personnel (i.e., one hour per nurse/nurse assistant per year), \$600 per bed



for software maintenance and upgrades, \$950 per bed to replace the bed sensors annually, and \$200 per bed to extend the warranty.

### *Implementation Benefits*

The benefits attributable to the monitoring system included a reduction in (i) hospital length of stay (LOS), (ii) ICU LOS for patients transferred from the general medical-surgical unit to ICU, and (iii) pressure ulcer (stage-two and above) incidence (see Table 2). The impact of the intervention is fully described in our prior paper,<sup>(10)</sup> but in short LOS decreased from 4.0 to 3.6 days ( $p=0.03$ ) and total ICU days were 47.2% lower ( $p=0.05$ ) after the intervention. For pressure ulcer incidence, we used data from a subset of patients comparing a 6-month post implementation period to a 4-month pre implementation period. This comparison has shown a reduction of stage-two and above pressure ulcers from 6 to 2 per 1000 patients ( $p=0.04$ ).<sup>(12)</sup> Based on the published literature, we obtained figures for the cost of a hospital day (\$1,448),<sup>(13)</sup> ICU day (\$2,575),<sup>(13)</sup> and an incidental pressure ulcer (\$15,229 per case).<sup>(14)</sup> The cost savings estimation did not include reduction in falls incidence, however, since published data did not categorize the falls into those that caused injury and those that did not. The benefits that accrued from improved workflow and efficiency like, for example, improved nursing time utilization were not included in the analysis.

### *Return on Investment Model*

An ROI model period of five years was selected. Costs and benefits were modeled quarterly. We assumed that the implementation of EarlySense<sup>TM</sup> would be accomplished in the first quarter (based on the community hospital experience) and the benefits would start to accrue from the second quarter onwards. All costs and benefits were discounted at a 7% annual percentage rate using the standard rate set by the U.S.

Office of Management and Budget (OMB) for its economic analyses.<sup>(15)</sup> We calculated annualized values by converting the discounted costs and benefits into a series of equal annual payments. The ROI was calculated by subtracting the total discounted implementation costs from total discounted cost savings, then dividing the amount by total costs. All costs and benefits were converted to 2011 U.S. dollars using the Bureau of Labor Statistics' Producer Price Index for General Medical and Surgical Hospitals.<sup>(16)</sup> We also abstracted from the problem of inflation in years following implementation by expressing costs and the discount rate in real terms.

The model extrapolated unit census from the baseline period (1,433 admissions) and intervention period (2,314 admissions) to represent a full year (1,910 and 3,090 admissions, respectively), assuming 80% of patients were covered by prospective payment systems (PPS), and that direct variable costs composed 42% of total costs.<sup>(17)</sup> In the sensitivity analyses, annual average admissions were varied from 1,910 to 3,090 patients, the real discount rate for costs and benefits from 3% to 10%, the rate of direct variable costs from 37.8% to 46.2%, and the proportion of patients in PPS from 60% to 90%, to reflect the rates of most US community hospitals. We also varied the difference in patient average length of stay in general medical-surgical unit from 0.27 to 0.41 (+/- 20%), the difference in ICU average length of stay from 1.60 to 2.40 (+/- 20%), and the difference in the percentage of patients with pressure ulcers from 0.56% to 0.84% (+/- 20%).

## **Results**

### *The California Hospital Medical Center Experience*

In the 5-year ROI model (Table 3), CHMC spent approximately \$274,000 in capital costs, \$15,000 in one-time noncapital costs, and \$293,000 in ongoing operational costs to implement the EarlySense<sup>TM</sup> system. Over this time period, the system saved

between \$3,268,000 (Conservative Model B) and \$9,089,000 (Base Model A), given an 80% prospective reimbursement rate. This resulted in a net benefit of between \$2,687,000 (\$658,000 annualized) and \$8,508,000 (\$2,085,000 annualized) respectively. The base case model (A) and conservative model (B) show an annual ROI of 292.8% and 92.5% (discounted over 5 years) with the hospital breaking even on the investment after 0.5 and 0.75 of a year, respectively. The average net benefit of implementing the EarlySense™ system ranged from \$224 per patient (Model B) to \$710 per patient (Model A) per year.

#### *Cumulative and Annual Benefits for California Hospital Medical Center*

In the base case model, the largest cumulative cost savings was from reduced LOS (\$6,141,000), followed by reduced ICU LOS (\$1,746,000), and then reduced pressure ulcers (\$1,201,000). (Table 2) Similarly, in the conservative model, cumulative cost savings were most heavily driven by decreased LOS (\$2,206,000), followed by reduced ICU LOS (\$557,000), and reduced pressure ulcers (\$505,000). The EarlySense™ system reduced the annual overall LOS and ICU LOS by 801 and 128 days, respectively, as determined by the clinical results of the intervention. The annual reduction in pressure ulcers was 16. Since the cumulative benefits are dependent on the length of intervention, we also determined that reduced length of stay saved the institution between \$541,000 (Model B) and \$1,505,000 (Model A) annually. The annual savings for a reduction in ICU LOS was between \$137,000 (Model B) and \$428,000 (Model A), with a reduction in pressure ulcers saving between \$124,000 (Model B) and \$294,000 (Model A) annually.

#### *Sensitivity Analyses*

Each of the most important parameters selected as the basis for our sensitivity analyses was individually varied, before combining them with all other key parameters, to

result in multi way sensitivity analyses for each range. The model was most sensitive to variations in average annual admissions and, secondly, to the proportions of patients under a prospective payment system (Figures A and B). We capped average annual admissions at 3,090 for one year (approx. 100% occupancy for the unit). The net benefit for variations in average annual admissions (1,910 to 3,090 patients) ranged from \$5,037,000 to \$8,508,000 (Model A) and from \$1,439,000 to \$2,687,000 (Model B) respectively, and for the proportions of patients under a prospective payment system (60% to 90%) ranged from \$6,236,000 to \$9,644,000 (Model A) and from \$1,870,000 to \$3,095,000 (Model B), respectively. The model was less sensitive to variations in the discount rate; the net benefit varied from \$7,955,000 to \$9,353,000 (Model A) and from \$2,500,000 to \$2,973,000 (Model B). A multi way sensitivity analyses was performed using the most and least favorable conditions for all variables. Unlike the other variables, a lower real discount rate of 3% reflected a more favorable outcome than a higher rate. This analysis yielded a net benefit of \$10,599,000 (Model A) and \$3,823,000 (Model B), and for the least favorable conditions, a net benefit of \$2,602,000 (Model A) and \$461,000 (Model B). The ROI for the sensitivity analysis ranged from 81.9% (16.4% annualized) Model B to 462.4% (92.5% annualized) Model A for the least favorable conditions, and from 772.1% (154.4% annualized) Model B to 2104.9% (421.0% annualized) Model A for the most favorable conditions.

## **Discussion**

The monitoring system appeared highly cost-effective, both in the base case and across a wide range of assumptions. The return on investment was outstanding, with the breakeven point within a year. The net benefit remained positive even when the most pessimistic assumptions were used in the sensitivity analyses.

Although there is growing evidence to demonstrate the effectiveness of new non-contact, vital sign monitoring systems,(18, 19) there have been almost no studies evaluating their cost effectiveness. One study examined the cost-effectiveness of the LG1 Intelligent Medical Vigilance System in reducing the rate of falls amongst neurosurgical patients.(20) This system consisted of two components: (a) a passive sensor array placed under the hospitalized patient's bed, and (b) a bedside unit that connects to the nurse call system. The authors calculated the cost effectiveness of moving from a baseline of using sitters to the bed sensor intervention. They were unable to monetize several important cost savings, including the detection of cardiac and respiratory problems, due to these data being unavailable. The authors concluded that the system might well be cost-effective if the unmeasured costs were included.

Health care institutions must often choose between different patient safety related interventions in order to maximize limited resources. Computerized physician order entry systems, electronic medical records, pharmacy bar coding systems, and smart pumps all have the ability to warn healthcare professionals about potential errors in the ordering, transcribing, dispensing or administering stages of the medication process. Our previous work has shown that it took over five years for a computerized physician order entry system to accrue a net benefit,(21) and a pharmacy bar coding system to obtain a net benefit of \$3.49 million.(22) Although it is difficult to compare interventions, our analysis shows a substantial net benefit of between \$2.69 million and \$8.51 million for the monitoring system, with the hospital breaking even on the investment after 0.5 and 0.75 of a year, respectively.

Although the EarlySense<sup>TM</sup> system has been shown to accurately and reliably measure patient heart and respiratory rate, the cost savings accrued to a healthcare institution from its implementation are dependent on the responsiveness of clinical staff. Clinical nursing staff need to promptly act on system alarms (either on the central station

or mobile devices) for patients who show signs of imminent clinical deterioration, an increased risk of developing pressure ulcers or falls. The Institute for Healthcare Improvement has strongly endorsed the use of rapid response teams for early intervention during medical crises,(23) although the effectiveness of rapid response teams has been variable.(24) In our study, the hospital had a rapid response team and it was operational during both the pre/post implementation periods. We hypothesize that the accuracy and reliability of the intervention in measuring patient heart and respiratory rate in this study, as well as the responsiveness of clinical staff, influenced the ICU LOS. Continuous monitoring devices have the potential to play a central role in the success of these intervention teams, especially on non-ICU wards, allowing for early recognition of clinical instability, rapid response and earlier transfer to ICU when needed.(10) This monitoring device can also observe a patient's mobility and activity level in real-time, thus allowing patients who are at an increased risk of developing pressure ulcers to be detected throughout the hospitalization.(8)

Some Electronic Medical Record (EMR) systems have the option for rule engines that scan patient data available in EMR and flag patients who may be at risk based on the known vital signs information, for example.(25) These are based on point measurements of vital signs usually four to eight hours apart, while the EarlySense system has the added advantage of accurately measuring patients' continuous heart and respiratory rate in real time. Young et al. showed how slow transfer to ICU was a significant predictor of death, with total hospital costs far greater for slow-transfer patients (\$34,000) compared to rapid-transfer patients (\$21,000) ( $p=0.01$ ).<sup>(3)</sup> The authors also suggested that a slow response to physiologic deterioration may explain these findings. Similarly, we propose that patients' acuity level would be reduced if they were transferred earlier to ICU, thus leading to shorter stays in the ICU and potential cost savings.

The cost savings associated with EarlySense™ implementation are also dependent on the reimbursement mix of capitated versus fee-for-service patients; the greater the proportion of patients under a prospective payment system (capitation and salaried payment),(26) the greater the net benefit. The continuous vital signs monitoring system may decrease utilization by assisting staff to intervene early with signs of patient deterioration. Although this leads to cost savings among capitated patients, a larger portion of savings among fee-for-service patients may accrue to the payer instead of the healthcare institution.(27)

### *Limitations*

Our ROI analysis has some inherent limitations. Firstly, we included only cost savings attributable to the reduction of LOS in a general medical-surgical unit, ICU LOS, and pressure ulcers. Changes in workflow related issues, like increased workflow efficiency, and provider productivity were not factored into the analysis, as reliable institutional estimates were not available. In addition, we chose not to include reduction in falls in the cost savings estimation, since they could not be categorized into those that caused injury and those that did not. Thus, the actual savings may actually be higher. Development of pressure ulcers may also be greater amongst immobile patients, so there may be more opportunities for additional cost-savings on geriatric wards, for example. Further studies are necessary to accurately understand the full value of these continuous monitoring systems for patients, in reducing pain and suffering, and also the cost of lawsuits following falls. Finally, as our study was based on a single site research, care should be taken when extrapolating these findings to other community hospitals or academic medical centers. Clearly, staffing resource will vary both within and between hospital sites, and thus the results would vary accordingly.

## **Conclusions**

Implementation of a continuous monitoring system in a 33-bed medical-surgical unit at one community hospital was associated with a highly positive ROI, when applying cost savings attributable to a reduction in LOS, ICU LOS, and pressure ulcers. Although further research in other sites is warranted, the magnitude and timing of these expected gains to the investment costs may justify the accelerated adoption of this system across remaining inpatient non-ICU wards. Other community hospitals may realize even greater cost savings, particularly if they have high numbers of admissions and greater than 80% prospective reimbursement rate. The use of such monitoring technologies has the potential to both improve safety and save money.

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## **Competing Interests:**

Sarah P. Slight MPharm Ph.D. PGDip - reports no conflicts of interest.

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Michael Olugbile MBBS MPH - reports no conflicts of interest.

Harvey V. Brown MD - has received consulting fees from EarlySense Inc.

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## Figure Legends

**Figure A.** Tornado diagram showing the one-way sensitivity analysis of net 5-year cost savings of intervention effects (Base Model A). Each bar depicts the overall effect on net benefits as that input is varied across the indicated range of values, while other input variables are held constant. The vertical line indicates the base case.

\* Average annual admissions were capped at 3,090 for one year (approx. 100% occupancy for the unit).

**Figure B.** Tornado diagram showing the one-way sensitivity analysis of net 5-year cost savings of intervention effects (Conservative Model B). Each bar depicts the overall effect on net benefits as that input is varied across the indicated range of values, while other input variables are held constant.

\* Average annual admissions were capped at 3,090 for one year (approx. 100% occupancy for the unit).